

CLAIMS

1. A micro-oscillation element, comprising:

- a movable main section;
- a first frame and a second frame;

5 a first connecting section that connects the movable main section and the first frame and defines a first axis of rotation for a first rotational operation of the movable main section with respect to the first frame;

10 a second connecting section that connects the first frame and the second frame and defines a second axis of rotation for a second rotational operation of the first frame and the movable main section with respect to the second frame;

 a first drive mechanism for generating a driving force for the first rotational operation; and

15 a second drive mechanism for generating a driving force for the second rotational operation;

 wherein the first axis of rotation and the second axis of rotation are not orthogonal.

20 2. A micro-oscillation element, comprising:

- a movable main section;
- a frame;

25 a connecting section that connects the movable section and the frame and defines an axis of rotation for a rotational operation of the movable section with respect to the frame;

 a first drive mechanism for generating a driving force for the rotational operation at a point relatively distant from the axis of rotation; and

a second drive mechanism for generating a driving force for the rotational operation at a point relatively close to the axis of rotation.

5 3. The micro-oscillation element according to claim 2, wherein the first drive mechanism and/or the second drive mechanism comprises a set of comb tooth-shaped electrodes.

4. The micro-oscillation element according to claim 3, wherein
10 the first drive mechanism and the second drive mechanism are constituted such that they can be operated under common control.

5. The micro-oscillation element according to claim 4, wherein the first drive mechanism and the second drive mechanism are
15 connected electrically in parallel.

6. The micro-oscillation element according to claim 3, wherein the first drive mechanism and the second drive mechanism are electrically separated, and are constituted such that they can
20 be operated under mutually independent control.

7. A micro-oscillation element, comprising:

a movable main section;

a frame;

25 a connecting section that connects the movable section and the frame and defines an axis of rotation for a rotational operation of the movable section with respect to the frame; and
a drive mechanism for generating a driving force for the

rotational operation, over points that change in distance from the axis of rotation continuously.

8. A micro-oscillation element, comprising:

- 5 a movable main section;
- a frame;

 a connecting section that connects the movable section and the frame and defines an axis of rotation for a rotational operation of the movable section with respect to the frame; and

- 10 a drive mechanism comprising a first comb tooth-shaped electrode and a second comb tooth-shaped electrode for generating a driving force for the rotational operation;

 the first comb tooth-shaped electrode and/or the second comb tooth-shaped electrode comprising electrode teeth having
15 a structure wherein an electrically separated first conductor section and second conductor section, and an insulating section interposed between the first and second conductor sections, are layered in the direction of the rotational operation.

20 9. A micro-oscillation element, comprising:

- a movable main section;
- a frame;

 a connecting section that connects the movable section and the frame and defines an axis of rotation for a rotational
25 operation of the movable section with respect to the frame; and

- a drive mechanism comprising a first comb tooth-shaped electrode and a second comb tooth-shaped electrode for generating a driving force for the rotational operation;

the first comb tooth-shaped electrode comprising electrode teeth having a structure wherein an electrically connected first conductor section and second conductor section, and an insulating section interposed between the first and second conductor sections, are layered in the direction of the rotational operation; and

the second comb tooth-shaped electrode comprising electrode teeth consisting of a third conductor section that opposes the first conductor section and does not oppose the second conductor section, when the element is not driven.

10. The micro-oscillation element according to claim 9, wherein the first conductor section and the third conductor section are of different lengths in the direction of rotational operation.

11. The micro-oscillation element according to claim 9, wherein at least one electrode of the set of comb tooth-shaped electrodes has a base section and electrode teeth extending from the base section, the electrode teeth having regions that gradually increase in width or thickness towards an end of the base section side.

12. The micro-oscillation element according to claim 9, wherein at least one electrode of the set of comb tooth-shaped electrodes has a base section and electrode teeth extending from the base section, the electrode teeth having regions that gradually increase in width as approaching the other comb tooth-shaped electrode.

13. The micro-oscillation element according to claim 1, wherein the first connecting section has a cavity section that becomes wider as approaching the movable main section, in addition to which, or instead of which, the second connecting section has
5 a cavity section that becomes wider as approaching the first frame.

14. The micro-oscillation element according to claim 9, wherein the connecting section has a cavity that becomes wider as
10 approaching the movable section.

15. A method for driving a micro-oscillation element, the element comprising a movable section, a frame, a connecting section that connects the movable section and the frame and
15 defines an axis of rotation for the rotational operation of the movable section with respect to the frame, and a first comb tooth-shaped electrode and a second comb tooth-shaped electrode for generating a driving force for rotational operation,

wherein the first comb tooth-shaped electrode has
20 electrode teeth comprising a first conductor section and a second conductor section aligned in parallel with the direction of rotational operation;

wherein the second comb tooth-shaped electrode has electrode teeth comprising a third conductor section that
25 opposes the first conductor section and does not oppose the second conductor section when the element is not driven;

the driving method comprises:

a first step for causing the movable section to perform

rotational operation in a first direction by generating an electrostatic attraction between the second conductor section and the third conductor section; and

5 a second step for causing the movable section to perform rotational operation in a second direction, opposite to the first direction, by generating an electrostatic attraction between the first conductor section and the third conductor section, subsequently to the first step.

10 16. The method for driving a micro-oscillation element according to claim 15, wherein the micro-oscillation element further comprises: a third comb tooth-shaped electrode and a fourth comb tooth-shaped electrode for generating a driving force for rotational operation;

15 the third comb tooth-shaped electrode having electrode teeth comprising a fourth conductor section and a fifth conductor section aligned in parallel with the direction of rotational operation;

the fourth comb tooth-shaped electrode having electrode
20 teeth comprising a sixth conductor section that opposes the fourth conductor section and does not oppose the fifth conductor section when the element is not driven;

the driving method further comprising:

a third step for causing the movable section to perform
25 rotational operation in the second direction by generating an electrostatic attraction between the fifth conductor section and the sixth conductor section, subsequently to the second step; and

a fourth step for causing the movable section to perform rotational operation in the first direction by generating an electrostatic attraction between the fourth conductor section and the sixth conductor section, subsequently to the third step.

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17. The method for driving a micro-oscillation element according to claim 16, wherein, in the second step, an electrostatic attraction is generated between the fourth conductor section and the sixth conductor section.

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18. The method for driving a micro-oscillation element according to claim 16, wherein, in the fourth step, an electrostatic attraction is generated between the first conductor section and the third conductor section.

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19. The method for driving a micro-oscillation element according to claim 16, wherein the first, second, third and fourth steps are respectively implemented during time periods corresponding to one quarter of a cycle of the rotational operation.

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20. A method for driving a micro-oscillation element, the element comprising: a movable section, a frame, a connecting section that connects the movable section and the frame and defines an axis of rotation for the rotational operation of the movable section with respect to the frame, a first comb tooth-shaped electrode and a second comb tooth-shaped electrode for generating a driving force for rotational operation, and a third comb tooth-shaped electrode and a fourth comb tooth-shaped

electrode for generating a driving force for rotational operation at a position closer to the axis of rotation than the first and second comb tooth-shaped electrodes;

wherein the driving method comprises:

5 a first step for causing the movable section to perform rotational operation in a first direction by generating an electrostatic attraction between the first comb tooth-shaped electrode and the second comb tooth-shaped electrode, as well as generating an electrostatic attraction between the third comb
10 tooth-shaped electrode and the fourth comb tooth-shaped electrode; and

 a second step for causing the movable section to perform rotational operation in a first direction by generating an electrostatic attraction, following the first step, between the
15 third comb tooth-shaped electrode and the fourth comb tooth-shaped electrode.

21. The method for driving a micro-oscillation element according to claim 20, further comprising a third step, for causing the
20 movable section to perform rotational operation in a second direction, opposite to the first direction, by generating an electrostatic attraction between the first conductor section and the second conductor section, subsequently to the second step.

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22. The method for driving a micro-oscillation element according to claim 21, wherein the first step and third step are both implemented during a time period corresponding to one quarter

of a cycle of the rotational operation.

23. The method for driving a micro-oscillation element according to claim 20, wherein the micro-oscillation element further
5 comprises a fifth comb tooth-shaped electrode and a sixth comb tooth-shaped electrode for generating a driving force for rotational operation, and a seventh comb tooth-shaped electrode and eighth comb tooth-shaped electrode for generating a driving force for rotational operation at a position closer to the axis
10 of rotation than the fifth and sixth comb tooth-shaped electrodes;

wherein the driving method further comprises:

a fourth step for causing the movable section to perform rotational operation in a second direction by generating an electrostatic attraction between the fifth comb tooth-shaped
15 electrode and the sixth comb tooth-shaped electrode, as well as generating an electrostatic attraction between the seventh comb tooth-shaped electrode and the eighth comb tooth-shaped electrode, subsequently to the third step; and

20 a fifth step for causing the movable section to perform rotational operation in a second direction by generating an electrostatic attraction, following the fourth step, between the seventh comb tooth-shaped electrode and the eighth comb tooth-shaped electrode.

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24. The method for driving a micro-oscillation element according to claim 23, further comprising a sixth step for causing the movable section to perform rotational operation in the first

direction by generating an electrostatic attraction between the fifth comb tooth-shaped electrode and the sixth comb tooth-shaped electrode, subsequently to the fifth step.

5 25. The method for driving a micro-oscillation element according to claim 24, wherein the fifth step and sixth step are both implemented during a time period corresponding to one quarter of a cycle of the rotational operation.

10 26. A method for driving a micro-oscillation element, the element comprising: a movable section, a frame, a connecting section that connects the movable section and the frame and defines an axis of rotation for the rotational operation of the movable section with respect to the frame, a first comb
15 tooth-shaped electrode and a second comb tooth-shaped electrode for generating a driving force for rotational operation, and a third comb tooth-shaped electrode and a fourth comb tooth-shaped electrode for generating a driving force for rotational operation at a position closer to the axis of rotation than the
20 first and second comb tooth-shaped electrodes;

the first comb tooth-shaped electrode having electrode teeth comprising a first conductor section and a second conductor section aligned in parallel with the direction of rotational operation;

25 the second comb tooth-shaped electrode having electrode teeth comprising a third conductor section that opposes the first conductor section and does not oppose the second conductor section when the element is not driven;

the third comb tooth-shaped electrode having electrode teeth comprising a fourth conductor section and a fifth conductor section aligned in parallel with the direction of rotational operation; and

5 the fourth comb tooth-shaped electrode having electrode teeth comprising a sixth conductor section that opposes the fourth conductor section and does not oppose the fifth conductor section when the element is not driven;

wherein the driving method comprises:

10 a first step for causing the movable section to perform rotational operation in a first direction by generating an electrostatic attraction between the second conductor section and the third conductor section, as well as generating an electrostatic attraction between the fifth conductor section
15 and the sixth conductor section; and

a second step for causing the movable section to perform rotational operation in a first direction by generating an electrostatic attraction, following the first step, between the fifth conductor section and the sixth conductor section.

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27. The method for driving a micro-oscillation element according to claim 26, further comprising: a third step for causing the movable section to perform rotational operation in a second direction, opposite to the first direction, by generating an
25 electrostatic attraction between the first conductor section and the third conductor section, between the second conductor section and the third conductor section, and between the fourth conductor section and the sixth conductor section, subsequently

to the second step; and

a fourth step for causing the movable section to perform rotational operation in the second direction by generating an electrostatic attraction, following the third step, between the first conductor section and the third conductor section, and
5 between the fourth conductor section and the sixth conductor section.

28. The method for driving a micro-oscillation element according
10 to claim 27, wherein the micro-oscillation element further comprises a fifth comb tooth-shaped electrode and a sixth comb tooth-shaped electrode for generating a driving force for rotational operation, and a seventh comb tooth-shaped electrode and eighth comb tooth-shaped electrode for generating a driving
15 force for rotational operation at a position closer to the axis of rotation than the fifth and sixth comb tooth-shaped electrodes;

the fifth comb tooth-shaped electrode having electrode teeth comprising a seventh conductor section and an eighth
20 conductor section aligned in parallel with the direction of rotational operation;

the sixth comb tooth-shaped electrode having electrode teeth comprising a ninth conductor section that opposes the seventh conductor section and does not oppose the eighth
25 conductor section when the element is not driven;

the seventh comb tooth-shaped electrode having electrode teeth comprising a tenth conductor section and an eleventh conductor section aligned in parallel with the direction of

rotational operation; and

the eighth comb tooth-shaped electrode having electrode teeth comprising a twelfth conductor section that opposes the tenth conductor section and does not oppose the eleventh
5 conductor section when the element is not driven;

wherein the driving method further comprises:

a fifth step for causing the movable section to perform rotational operation in a second direction by generating an electrostatic attraction between the eighth conductor section
10 and the ninth conductor section, as well as generating an electrostatic attraction between the eleventh conductor section and the twelfth conductor section, subsequently to the fourth step;

a sixth step for causing the movable section to perform
15 rotational operation in a second direction by generating an electrostatic attraction, following the fifth step, between the eleventh conductor section and the twelfth conductor section;

a seventh step for causing the movable section to perform rotational operation in a first direction by generating an
20 electrostatic attraction between the seventh conductor section and the ninth conductor section, between the eighth conductor section and the ninth conductor section, and between the tenth conductor section and the twelfth conductor section, subsequently to the sixth step; and

25 an eighth step for causing the movable section to perform rotational operation in the first direction by generating an electrostatic attraction, following the seventh step, between the seventh conductor section and the ninth conductor section,

and between the tenth conductor section and the twelfth conductor section.

29. The method for driving a micro-oscillation element according to claim 28, wherein, in the third step and the fourth step, an electrostatic attraction is generated between the seventh conductor section and the ninth conductor section, and between the tenth conductor section and the twelfth conductor section.
30. The method for driving a micro-oscillation element according to claim 28, wherein, in the seventh step and the eighth step, an electrostatic attraction is generated between the first conductor section and the third conductor section, and between the fourth conductor section and the sixth conductor section.